Applicant: Slovak University of Technology in Bratislava

Project: Knowledge-based Faculty for Economic Practice

ITMS code of project: 26110230113

Activity: 3.2

Responsible for activity: PhDr. Kvetoslava Rešetová, PhD.

THE INSTITUTE of APPLIED INFORMATICS, AUTOMATION AND MECHATRONICS – PROFILE PRESENTATION

Name of activity	**Activity 3.2** Building the tools for knowledge transfer into education
Specific objective	**3. Building the tools for knowledge transfer into education**
Aim of activity	The activity of building the tools for knowledge transfer into education concludes the information flow attained from the analysis of environment impact, and sets up specific tools for the knowledge transfer into education. It is aimed at building a set of tools for transferring the knowledge collected in the previous activities into education at the Faculty, thus enhancing the knowledge base of the target group, while focusing on the functionality of the knowledge transfer to the target group.
Date of activity Implementation	10/2013 – 09/2015

Project part: activity 3.2 : 1. Tool for knowledge transfer – profile research presentations

The Faculty research is oriented particularly on the following fields:

- research in materials with focus on the research, development and technological processing of the main types of engineering materials,
- research and development of new technologies in industrial production oriented mainly on technological processing of modern technical materials and environment-friendly production,
- research in identification, automation and control of processes as well as information security of the technology, production and organizational systems,
- research and verification of principles of managerial control and its organizational structures,
- research in quality and certification of processes and products,
- research in safety and reliability of technological devices and systems with emphasis on the methods of systems analysis and synthesis.

The defined research characteristics reflect the Faculty research fields, and are subject to the Faculty evaluation processes. **The current profile presentations comprise the research profile, its identification and recording in a new way**. The Faculty experts in the research fields make the audience familiar with the research characteristics, research and development orientation, so that to provide a comprehensive research profile of the Faculty institutes (there are six institutes at the Faculty) in both Slovak and English languages. The elaboration of text in an adequate number of quires, text translation and copyright rules – all this is subject to the method of the profile presentation implementation. The elaborated profile presentations might be an important material source for:

- training at the Faculty in its key subjects
- domestic and international presentation of the Institute
- enhancement of the advertising space for promotion purposes of the project
- innovative elaboration of the Faculty research contents.

Defined project outcomes:

The project outcomes will be determined by successful implementation of the project activities, particularly activity 1.1 - stakeholding, activity 2.1 - portal of companies, activity 3.1 -implementation from acquired e-sources. Such interaction along with the information flow can influence the success of knowledge transfer into education. The outcomes of previous activities will be utilized in this final activity which should provide space particularly for knowledge transfer and improvement of knowledge base, and simultaneously provide a space for meeting the main project aim. Specific outcomes of the activity will be as follows:

- **six profile presentations mapping the research character of six Faculty institutes, applicable in training and with strong potential for the Faculty promotion**
- production of minimum 30 virtual records of technological procedures outsourced from economic practice and applicable in education, i.e. enhancement of information on applicability for the Faculty doctoral students
- production of minimum 30 virtual records of the Faculty technological procedures and processes, for application in the Faculty education, and for the purposes of comparison of the

technological processes and theoretical knowledge acquired in the Faculty training to the knowledge acquired in practice
- four expert lectures for doctoral students (and also for interested Faculty researchers), forming the knowledge base of the target group in four principle science fields.

Implementation of activity:

1. In compliance with the project aims, the activity was introduced to the Heads of the STU MTF Institutes: **Appendix 1**: Information for institutes of 12 Dec 2013 , **Appendix 2** : Letter to the Heads of the STU MTF Institutes of 21 Jan 2014
2. Heads of the STU MTF Institutes delegated in writing an Institute representative who will be in charge of the profile presentation elaboration – letters to Heads of the Institutes are in the project archive of the principle investigator
3. Individual meetings of the principle investigator with related employees with focus on structure and contents of profile presentations
4. Collection of data, text modifications, graphical design of presentations
5. Text translation
6. Final arrangement of presentations into e-proceedings of scientific papers
7. Publicizing the profile presentations

Guarantors of profile presentations:

Institute of Materials – Mgr. Marián Palcut, PhD.

Institute of Production Technologies – Assoc. Prof. Ing. Erika Hodúlová, PhD.

Institute of Industrial Engineering and Management – Assoc. Prof. Ing. Helena Makýšová, PhD.

Institute of Safety, Environment and Quality – Prof. Ing. Maroš Soldán, PhD.

Institute of Applied Informatics, Automation and Mechatronics – Prof. Ing. Pavol Tanuška, PhD.

Advanced Technologies Research Institute – Assoc. Prof. Ing. Maximilián Strémy, PhD.

Introduction

The orientation of STU MTF research activities comes out from the Faculty profile in pedagogy and is in compliance with the long-term development of the Slovak University of Technology in Bratislava and covers the all spectrum of the education at STU MTF. The activities of STU MTF researchers are implemented as follows:

- projects of base research supported by VEGA grant agency,
- projects of applied research supported by KEGA grant agency,
- projects investigated within international programmes,
- projects of international scientific and technical cooperation,
- projects of base and applied research supported by APVV grant agency,
- contractual research and development (business contracts).

1. Science and Research in STU MTF

Vision of STU MTF

The STU Faculty of Materials Science and Technology in Trnava, in compliance with the STU vision, intends to be a research oriented and internationally renowned faculty within the similar faculties framework, i.e. the faculties developing modern trends in research and industrial production with focus on progressive materials, sophisticated production technologies and industrial management, automation and IT implementation of production and technological processes such as quality, safety, as well as environmental and managerial aspects of industrial production.

Mission of STU MTF

In compliance with the defined mission of the Slovak University of Technology, the STU Faculty of Materials Science and Technology intends to actively contribute to meeting the requirements of the mission – with the priority laid on materials science and production technologies – in accredited fields of education, research and development within the stipulated competences:

- provide the university system of education in all stages in accredited study programmes
- disseminate, improve and develop knowledge by the research and development tools,
- ensure transfer of research results into educational process,
- ensure transfer of research results into entrepreneurial practice,
- protect its research results,
- integrate into the system of university life -long learning,
- participate in sustainable development of society with all its activities, mainly by the development of the student personality in the context of humanism and democracy ideals.

General and strategic goals of research

1. Publish the research and creativity results internationally, particularly in the renowned international scientific journals.
2. Increase the STU MTF status in the projects of international cooperation.
3. Build the research infrastructure (equipment) including the qualified service.
4. Intensify the cooperation with practice, ranging from private industrial companies to public institutions and authorities.
5. Focus the research results and free investigation also on the outcomes, e.g. patents.
6. Improve the orientation on other than grant sources from the state budget, particularly on the sources from abroad, project grant agencies and entrepreneurial activity.

The scientific and research activity of STU MTF is carried out in the forms of:

- projects of the base and applied research and development,
- projects solved within the international programmes,
- projects of the international scientific collaboration,
- projects of contractual research.

The research content is focused on the following areas:

- materials research with a focus on the research, development and technological processing of the basic and advanced types of technical materials,
- research, development and optimisation of the new technologies of industrial production, oriented particularly on the technological processing of advanced technical materials and ecologically clean processes and products, and the numerical simulation of technological processes,
- process identification, automation and control, as well as information support for technological, production and organisation systems,
- research and verification of the managerial control principles and their organisation structures,
- quality control and certification of processes and products,
- safety and reliability of technological equipment and systems, while emphasising the methods of system analysis and synthesis.

2. Profile presentation of the Institute of Applied Informatics, Automation and Mechatronics

2.1 Institute characteristics

The research at the Institute of Applied Informatics, Automation and Mechatronics (UIAM) is oriented on the fields of informatics implementation and automation of control processes on all levels of industrial production and it reflects the modern trends of control processes according to the pyramidal model.

The basic strategy of UIAM comes strictly out of the European legislation requirements for the processes harmonization for the development and operation of hierarchic control systems as well as from the requirements for the vertical integration of information systems control.

The orientation of UIAM research is defined by the efforts to meet the global goals of human civilization development:

- by automation means contribute to the decrease of energy consumptions at maximum, which has the direct impact on the environmentalism,
- by thorough elaboration of general requirements stipulated in international standards carry out the development of safety critical control systems, which has an impact on security increase and health protection,
- by utilizing the modelling and testing of complex software products increase the effectiveness of development and sustain the hierarchic systems process control.

Based on these principles the UIAM research is oriented on the following fields:

1. ***Research and development in compliance with requirements of Plants for the Future“:***
    - design of intelligent control methods and artificial intelligence implementation into control,
    - utilization of virtual reality and computer simulation means,
    - simulation and optimization of processes and systems,
    - Big Data and knowledge acquisition from production databases in hierarchic processes control,
    - design of methodologies and documentary procedures within the product life cycle and technologies sustaining the good practice principles,
    - horizontal and vertical integration of information and control systems (MII concept),
    - design of methodologies for testing the control processes software,
    - identification and optimization of control parameters influencing the safety improvement of industrial processes control,
    - development in the field of security critical control systems.

2. ***Support of base research transfer into practice:***

- base research in the field of controlling the joined and discrete non-linear dynamic systems,
- design of control algorithms based on the dynamic systems theory,
- control of dynamic systems with fast feedback,
- utilization of the Theory of graphs in the proposal of complex network structures.

The scientific profile of UIAM is in compliance with the trends stipulated by Industry 4.0 Concept.

Within the University Scientific Park Project (2013-2015) the Institute of Applied Informatics, Automation and Mechatronics builds up the workplace of **Automation and ICT Implementation of Production Processes and Systems** (AIVPS) as a flexible system of automated control of technological and production systems.

The main focus of the newly prepared workplace is put on establishing a powerful regional centre of excellence oriented particularly on automotive and electrical industry represented significantly in the region (VW, Peugeot-Citroen, ZF, Samsung, Foxconn, etc.). The new workplace of AIVPS will boost the innovations transfer into industry.

2.2 Philosophy of Institute´s scientific research and pedagogical activities

The basic philosophy of the Institute´s scientific research and pedagogical activities is represented by the pyramidal model of processes control.

In hierarchic control systems each department or subsystem deals only with the tasks of their own level. The initial information supporting the decision and calculation of control signals (interventions) is transferred from lower levels upwards and the control signal (interventions) from the upper levels downwards. In complex systems, such as control systems for specific industrial branch, business company or electric system we distinguish three or more control levels.

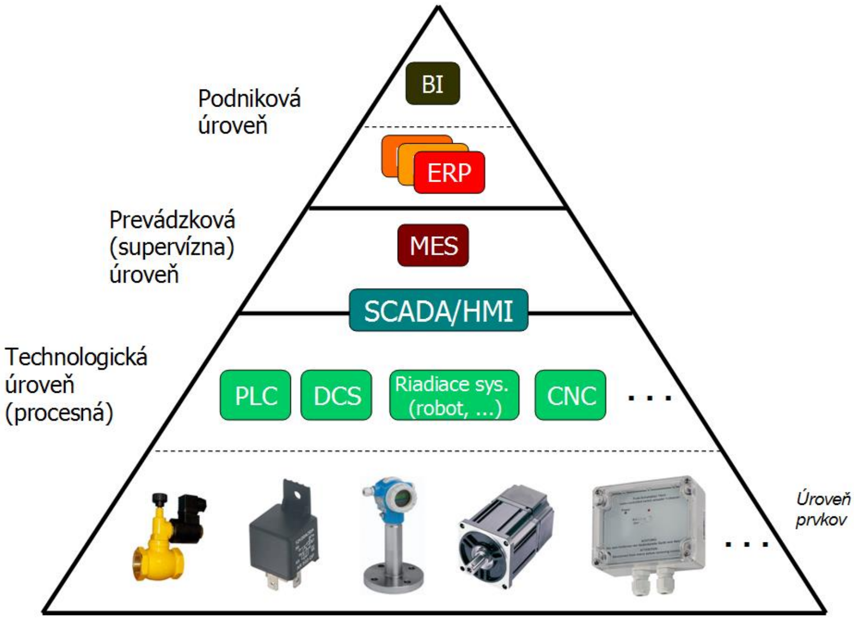

Fig. Pyramid model

In automated control systems the control automats and regulators controlling the mechanisms movement and machine functions together with sensors monitoring the course of the production process represent the lowest control level – process level.

The information monitored and measured by sensors is sent to the operator panel or control computers which are on the operational level. The components on this level evaluate the accuracy of the individual operations to be executed and generate the orders or required values for the process level components.

On the top of pyramid model there is the company level. There are information systems whose primary task is to help the managers analyse the environment the organization operates with focus on long-term trends determination as well as long-term strategic decisions.

The Institute´s activities are oriented on the field of ICT implementation and automation of control processes on all levels of the industrial production control and they reflect the modern trends of process control according to the pyramid model briefly introduced.
Currently, the Institute´s research is built on four basic pillars including the research results implementation into practice. They are as follows:
1. Systems of process control level
2. Simulation of production systems
3. Acquisition of knowledge from databases in hierarchic control of technological and production processes
4. Analysis of joined non-linear dynamic systems with fast feedback

2.2.1 Systems of process control level

Applied automation plays an important role in the Automation and ICT Implementation of Processes study programme. The research, pedagogy as well as the cooperation of the Institute with practice is strategically oriented within the aforementioned context. Similarly, it is the same for the field of process level in the hierarchic model of process control representing the first of four pillars mentioned.

The process level represents the primary source of information and the direct means for control interventions execution. The Institute´s research activities concentrate mainly on:

1. design, implementation, testing and documentation of control via industrial programmable regulators
2. implementation of logic control systems
3. control of security critical systems
4. ensuring of control systems life cycle in compliance with EU regulations.

The control of joined processes represents the interdisciplinary field where it is first necessary to manage the control process physical base theoretically, and subsequently utilize the control theory possibilities implemented in the application software of industrial regulators. The Institute´s research is oriented on developing the virtual industrial regulators, particularly on developing the systematic approaches such as maximum utilization of the given regulator´s application software.

The approach allows for significant costs decrease for students education and organization of trainings delivered by practitioners as the purchase or real industrial regulators is not necessary. For instance, the trainings for UDC 3300 were successfully delivered for ProCS Šaľa, Hlinikáreň

(Aluminium Works) Žiar nad Hronom, or for teachers of secondary vocational schools. Within the research the special virtual models of various technological processes were developed for the educational purposes allowing thus the simulation of real process control situation.

UIAM has also real industrial regulators at its disposal and experience show that the operator´s transition from a virtual to real one is comfortable, practically, the tests results showed no drawbacks in using the real industrial regulators. Therefore, within the research it was necessary to fully verify the industrial regulator configuration operation in a real time.

The Institute also deals with the matter of intelligent houses. Here the issues of HW optimization and SW equipment, the functions classification of í intelligent houses were investigated as well as the model house for the research purposes was built.

Part of the Institute´s research deals with the life cycle security of control systems, particularly with the life cycle stages related to documenting all the processes in compliance with international standards.

For instance, it is the way how to set up the user´s specifications of the control system, or functional and other specifications. The Institute deals with the methodology of verification and validation of these specifications in order to make the administration automated. Simultaneously, the research results are implemented in the education as well. Special attention is paid to the verification and validation process in which the systematic procedure for continuous monitoring of testing, to what extent the requirements of the project are met is developed.

Another important part of automation is represented by the discrete processes whose control is built on the principle of finite automats and where it is necessary first to manage logical sequences and controlled processes sequences in order to apply theoretical knowledge in the design and implementation of plc (programmable logic control) software. The Institute´s research activities in the field are oriented mainly on the development of security critical control systems in compliance with general requirements set by international standards influencing the improvement of safety and health protection as well as the enhancement of operation safety of risk technologies.

The Institute also deals with the continuous development of physical models of real production systems allowing thus the students to obtain practical skills not only in the field of the design and implementation of control algorithms but also in the field of introducing the systems into operation as well as in the field of their diagnostics. The trainings in the field were carried out e.g. for JAVYS a. s., FESTO s. r. o.

The visualization systems of processes and operator control are an inseparable part. These systems have to ensure the interaction of the controlled technology and service personnel. The aforementioned visualization interface is the part of all pyramid model levels of processes control.

Implemented projects

Within the research in the field of process control level the Institute cooperates with commercial practice. The results of this cooperation are represented by several projects implemented not only in the field of the design and implementation of new device control systems but also in renovations and improvements of existing older technological devices.

For instance, the cooperation with VUJE a. s. resulted in the design and implementation of the control system and application program equipment of an inspection stand for monitoring the state of burnt-up nuclear fuel. The aforementioned device allows executing more examinations on fuel assemblies so that their degradation during the wet storage in a temporary repository can be monitored.

One of the next projects implemented for VUJE a. s. is represented by the design and implementation of support measuring system to control the course and evaluation of experiments aimed at nuclear and radiation cask safety for burnt-up nuclear fuel.

In cooperation with automotive industry the Institute carried out several projects, with VW Slovakia a. s. in particular, e. g the design and implementation of a measurement and evaluation workplace using laser measuring head. The system provides an accurate fixation of a car body onto an assembly conveyor platform.

On the final assembly line of VW Touareg and Porsche Cayenne cars the Institute executed the design and implementation of the control system for a hybrid batteries manipulator. The pilot setting up of the automated conveyor return into the starting position in the beginning of the tact while detecting the obstacles or service in the return position was carried out by using a security laser scanner. The aforementioned system became the reference for further similar manipulators on the line.

In cooperation with plastic industry the Institute executed the control systems renovation of two older Technologies determined for cutting of expanded polystyrene. The first of them was the saw for cutting the building cover polystyrene with automated setting of production parameters.

The other one was the contour saw for cutting of complex shape products. The original inhomogeneous control system was replaced by Sinumerik complex control CNC system. The new device not only enhanced the productive possibilities of the saw but significantly simplified the production preparatory process and device operation as well.

The Institute employees implement the projects not only in Slovakia but abroad as well. One of the foreign projects is represented by the implementation of a prototype line for driver and co-driver´s seats assembly for a Spanish customer. It was a specialty that during this project four similar assembly lines were built in two Spanish cities 600km afar. From the functional point of view the lines were interesting due to the possibility of fast configuration of the technological assembly procedure. The incorporation of Poka Yoke, Pick - To - Light technologies as well as monitorability and agreement were obvious in this modern system.

Beside the projects financed by the end user the Institute deals also with the projects financed by European structural funds. Here the Institute cooperates e.g. with Qintec Company s. r. o., particularly on developing the devices and application software for the telemetric acquisition systems of measured data aimed at monitoring and evaluating the radiation situation in the Nuclear Power Plant (NPP) surroundings in order to increase the civilians safety.

2.2.2 Simulation of production processes

The aforementioned activities belong to the first pillar of the Institute´s research. The second pillar is represented by the simulation of production processes.

Simulation provides solutions to various problems occurring in real/virtual systems. The simulation is the process of model design, its transformation into a simulation model in the specific environment of a simulator as well as experimenting with the simulation model to learn about the system´s behaviour or its properties improvement. It is obvious that no model is usable universally, i.e. each specific problem or system needs its own specific model.

We deal with the simulation understood as discrete events controlled simulation allowing monitoring e.g. the current state of the company production in detail. The simulation in these terms can become an important part of the production systems control or projecting, in other words: it allows setting up the way of production assignments, their sequence as well as the system transfer, optimization of production batches size, minimization of idle times, evaluation of various control strategies, or execution of reliability analysis. The main advantages of the simulation utilization are as follows:

- knowledge acquisition of system´s behaviour and its specifications without needing the real system,
- analysis and improvement of systems with continuous operation (without needing to stop their activities),
- communication improvement of system operators groups.

Implementation of simulation optimization in production processes control
The simulation optimization is used for finding the best solution from the amount of simulation experiments while it provides structural approach to the determination of input parameters optimal values where the optimum is measured by the output variables function from the simulation model. We can say that current optimization techniques represent robust algorithms usable for solving various real problems; nevertheless, as noticed by many authors, there is still a lot of scepticism about the simulation optimization results in specific applications. Regarding the use of simulation optimization it is necessary to mention that it is extremely demanding in terms of calculations and almost unusable without computer aid.

Software solution to simulation optimization
Software packages for simulation optimization are designed as plug-in modules to the basic simulation platform. The optimization module cyclically changes the values of input variables from defined ranges and according to the results of current simulation run it monitors the purpose function objective. The purpose function is understood e. g. as minimization of per unit production costs.

Algorithms for software solutions to simulation optimization

Obviously, there are many methods usable for simulation optimization; however, the most used ones in software packages for simulation optimization are represented by heuristic search algorithms. They provide good, acceptable and fast results for the variety of problems. Let us mention just few significant heuristic algorithms such as: genetic algorithms, evolution strategies, simulated annealing, taboo search, simplex search, etc.

Implementation of simulation optimization

Use of simulation optimization will be carried out in WITNESS 14 v simulator, product of British company Lanner Group Ltd. The simulator is oriented mainly on the simulation of production processes and systems, service systems, logistic systems and is based on the principle of the simulation controlled by discrete events.

General procedure of simulation optimization

Simulation optimization uses the following procedure:

1. The sets of parameters/inputs values for simulation experiments are defined and initialized (one or more for each run).
2. The results of the simulation run are obtained; the optimization module selects new parameters/inputs from the initialized set.
3. Steps 2 and 3 repeat until the optimization module algorithm is stopped manually or the requirements for algorithm accomplishment are met (investigated initialized set of inputs or else defined requirements).

This general procedure seems to be clear and very simple; nevertheless, its implementation is much more difficult.

With regard to simulation optimization we can ask how to eliminate the large amount of input variables. The optimization module provides several possibilities:

1. Use a suitable step of input parameters change or define only selected values (an appointed set of values origins).
2. Define the limits in terms of functional dependences of input variables.
3. Select a suitable algorithm for optimization.

Presentation of optimization simulation results

Optimization module provides reports on the course of optimization process and selected. The reports are presented in graphs and tables. It is possible to show also further selected functions documenting other simulation inputs.

Pros and cons of optimization simulation

The strengths of simulation optimization are as follows:

1. Simple use for various problems, e. g. for optimization of production objectives, determination of optimal production batch size, or determination of optimal production intervals, etc.
2. Simulation model can replace the real system more accurately than the mathematical model.
3. Definition of purpose function is very simple and requires no specific mathematical apparatus.
4. Determination of input variables and their limitations is quite simple as well (if a suitable analysis and problem classification is carried out).
5. Simulation optimization runs automatically (it is run by optimization module).
6. Results are clearly presented.

Simulation optimization provides real possibilities to solve the problems in production planning and control, e.g.:

- optimization of production objectives;
- optimization of production plans;
- optimization of production batch size;
- optimization of stock supplies;
- decision support in scheduling in real time.

Simulation optimization is a useful tool in the field of production systems projecting, e.g.:

- optimization of machines amount;
- optimization of transport means;
- optimization of workforce.

The weaknesses of the simulation optimization are as follows:

1. Simulation optimization has to operate with built simulation system model which is verified and validated.
2. Optimization can last too long.
3. Risk that the global problem will not be found or it will get stuck in the local extreme.
4. The result accuracy cannot be guaranteed as it is always a compromise of the accuracy and time in which we obtain the result.
5. The price of SW packages is too high.

Conclusion

Due to its simplicity and SW support the simulation optimization can be utilized for solutions to various problems, however, the selection of correct approach depends on the investigator, the simulation model designed and problem complexity. The simulation optimization can be used everywhere where it is possible to design the mathematical optimization model while designing the simulation model is quite intuitive and fast due to the help of simulation platforms.

The common trouble of all simulation experiments is to find the solution in the large set of experimental results. The problem can be solved efficiently by the optimization modules, e.g. for simulated annealing where tis possible to set only 1% from the set of possible experiments and the solution is found.

Despite the significant progress and development there are still many obstacles to overcome so that the simulation optimization becomes a strong tool for analysts responsible for optimization problems. We hope that it will become a common method for them, and will simplify their work.

Implemented projects

Optimization of costs related to the transport and tenancy of supplies for Plastic Omnium s. r. o., Lozorno, 2010

Simulation of production components for IKEA Company for IKEA Components s. r. o., Malacky, 2012

Performance evaluation of an assembly line for case lining via simulation for IAC Group s.r.o., Lozorno, 2010

Performance evaluation of an assembly line for door panelling for IAC Group s. r. o., Lozorno, 2010

Simulation of Colorado 2 Project production run-up for IAC Group s. r. o., Lozorno, 2009

Investigation of assembly inputs of integrated circuits via simulation for Invensys Slovakia, Trnava, 2012

Simulation of Hyundai, Kia lines for ZF BOGE Elastmetall Slovakia a. s., Trnava 2013

Simulation of pre-preparations line for ZF BOGE Elastmetall Slovakia a. s., Trnava 2013

Optimization of production batches of A components for MIBA Vráble 2014

Improvement of selected production system parameters for Hella Slovakia Front-Lighting, s. r. o., Kočovce, 2014

2.2.3 Knowledge acquisition from databases in hierarchic control of technological and production processes

Another field investigated by the Institute´s employees is the field of Business Intelligence (BI) which can be understood as a comprehensive and efficient approach to operation with company data influencing thus the correctness of strategic decisions. BI can be also understood as integration for information technologies, acquisition applications and methods, normalization, analysis, and data presentation and description.
Business Intelligence has to convert large amounts of data (mainly from data warehouses) into knowledge or knowledge necessary for the end user. The knowledge can be subsequently used in the control process to improve the quality, reliability as well as efficiency or profit rate increase.
The acquired knowledge is not only specific records or sets of records. They can be also acquired knowledge from monitoring a specific quantity in the managerial environment or knowledge determining data interdependences. Therefore, modern database servers comprise a large support for building of data warehouses, OLAP analysis (Online Analytical Processing) and data mining.
BI systems provide thorough analyses of large data amounts. Via data mining models we can predict e.g. from the history of data saved in in a file as well as the related process development in the future.

Information saved in database systems can be divided into two categories. The first category comprises the kind of information it has been constructed for and in accordance with them it is operated. Useful information is comprised in specific attribute values and their combinations regarding the relations given by database arrangement. The user can manipulate with the enquiries via enquiry language, e. g. by SQL.
The other category describes the information which at first sight is not obvious from the attributes values, nor from the database structure. This information is hidden in a large amount of database records and can be obtained by the methods of inductive derivation from the attribute values.

Regarding the knowledge sometimes the triangle scheme is introduced.
Data is understood as random groups of simple facts or events. More complex facts originated by the aggregation of simple fact knowledge are represented by information.
Knowledge results from our perception processes, and they are organized so that the conclusions can be derived of them.

Knowledge acquisition from production databases

Prior to the knowledge acquisition for the hierarchic processes it is necessary to execute the following stages:

- In stage 1 it is necessary to carry out the analysis of data character on all levels of the control processes pyramid model and subsequently, design the structure and functions of specialized data depository.
- In stage 2 it is important to verify and validate the correctness of the data depository design with regarding the existing international standards and regulations.
- Stage 3 is aimed at designing the subsystem of heterogeneous data structures transformation into a unified structure given by the data depository design.

Handling all three stages represents the prerequisite for achieving the objective, i.e. utilization of data warehouses for processes control via a subsystem with a hierarchic (multilevel) structure.

The proposed solution for knowledge acquisition for hierarchic processes control is illustrated in the following figure.
The solution is divided into three levels.

The basic level which is connected to the technological and/or to the production process itself via information is called the control level. It comes out from the standard pyramid model.
The proposed and projected control system on the technological level usually consists of the following subsystems:

- subsystem of measurement, acquisition and processing of information,
- subsystem of control (including the transfer of action signals to action members),
- subsystem of visualization and communication of the operator with the control system (SCADA/HMI),
- databases of real time (saving of technological data and transfer of these data to the analysis level are implemented),
- information systems on various control levels,
- subsystem of integration of information and control systems,
- subsystem of control support (simulates various kinds of technological and/or production process models as well as various kinds of production strategies, etc.).

It comprises all components and subsystems necessary for processes control of random industrial company as well as it ensures also other functions such as:

- measurement of immediate quantities values,
- monitoring of quantities (e.g. limit values, trends, etc.),
- managing the action members,
- manual operations,
- assignment of required regulators and logical control,
- visualization of data,
- archiving of data on process development,
- and transfer of information onto subordinate level.

Control systems for various process types are generally described by the following:

- control system technology is generally distributed,
- process control requires fast (dynamic) and failure free measurements,
- control process requires also fast and reliable communication subsystem for information transfer. i.e. it requires short reaction times at transfers,
- fast (dynamic) and reliable managing of action members (actuators),
- high operational reliability of the control system at HW or SW failure,
- and measured signals collection and processing is carried out cyclically in stated time intervals, etc.

The aforementioned control system properties are currently proposed projects and implemented via technological and prom means on the basis of local computer networks (decentralized control systems – numerical control components are connected to the communication subsystem).

The other level which has to be considered as subordinated is represented by the data analysis. It includes subsystems for data collection, extraction, transformation and integration, including the data warehouse or operational data depository. OLAP tools and Technologies are the component of the aforementioned system.

Fundamental requirement for extracting and processing the data from production databases is represented by preserving the data integrity. With regard to data transformation and processing into different data structures in a data depository it is a very complex and in many cases demanding requirement. Potential knowledge hidden in a large amount of data has to be prepared for processing in several steps whereas the data relations and bonds are not interfered.

It is particularly complicated with the data originated from the systems indicated as security critical. Security critical system, is such a system whose incorrect functionality (failure) can have a catastrophic impact such as human casualties, or serious injuries, enormous property or environment damages.
One of the basic properties of security critical systems is represented by real time included in the requirements of almost all security critical systems. Not only we need to acquire reliable measurement and processing results (technological data) we need to acquire them in a correct time.
Nowadays, the security critical processes occur more frequently than they did in the past. They are the part of operations, e.g. in chemical or pharmaceutical industry, nuclear industry, in control processes of burning and also in many other operations. Currently, the control of basic processes in production companies, mainly in machinery companies, belongs to the group as well.
Considering the aforementioned, we can say that a correctly proposed data pump, often called as ETT (ETL) process is alpha and omega of correctly proposed data warehouse. The basic factor ensuring the appropriate data pump functionality is represented by its verification and validation.

The last level which has to be understood as the highest one is the level of knowledge acquisition comprising KDD subsystem including the subsystem for knowledge description.
Only correctly acquired knowledge (using data mining methods and techniques) and described can be efficiently utilized for the control processes quality improvement. Therefore, the most important part of the system is represented by the knowledge description module. Correctly described knowledge has to be subsequently utilized and ensure their regressive transport into production process. This is carried out via: „Generator of interventions into production process“ module.
The module has to be taken as an interface between the knowledge acquisition and control levels.
The module itself is directly connected to SCADA/HMI system and via it the interventions in the production process are directly executed. It is necessary to add that the interventions with correctly acquired and correctly described knowledge can be carried out in manual and automated mode as well.
The information flow from the level of knowledge acquisition for a technological level can comprise also as follows:

- parameters of control algorithms,
- values of balance calculations,
- static and dynamic model parameters,
- parameters usable for device diagnostics – maintenance support, or materials for assuring the production quality, etc.

Via the application of the proposed solution into practice, the system of knowledge acquisition for hierarchic processes control can help to handle the following:

- Prediction of emergency states of a controlled process based on the principle of finding the analogical situation via processing a large amount of data in real time.
- Prediction of preventive controls of production devices relate to maintenance. Regular maintenance is expensive and moreover, the shutdown plan does not always correspond with the individual components life cycle.
- Identification of parameters influence on production process.
- Identification of moderately fault information sources (sensors) where the common techniques of related alarms limit estimation fail.
- Diagnostics of production systems with regard to total life of the systems.
- Identification and optimization of relevant control parameters influencing the security industrial processes improvement.
- Identification of fault activities of action members such as insufficient execution of calculated impact.
- Particularization of non- linear dynamic models of controlled processes aimed at parameters optimization.
- Continuous monitoring of control process quality on the basis of quality assessment from data obtained on-line.
- Detection of fault states of production devices as well as fault states individual products - identification of spoilage occurrence.
- Identification of various non-standard states influencing the production process and which have to be dealt with the production operator frequently by the shutdown of a machine or part of technology.
- Handling the troubles using the acquired knowledge without prior objective setting.
- A prediction for the company management needs and various ad hoc reports.
- Effective implementation and innovations of control systems on all levels.

Implemented projects

In the aforementioned research field the Institute executed several interesting projects for end users.

1. One of the projects was represented by the Concept design for verification and validation of integrated IS for the emergency centres of the Nuclear Power Plant JE-Mochovce, carried out for VÚJE, a. s. in 2008. The project was aimed at designing the concept and proposing the tasks for verification and validation of integrated information system for the emergency centres in JE - Mochovce.

2. The following project Methodology design and implementation of automated registration and evaluation of selected data was accomplished in 2001 for SE-EBO, a. s. The project was aimed at designing the methodology and subsequent implementation of automated registration and evaluation of monitored parameters in SE-EBO, a. s., while the information system allowed the monitoring of selected parameters and alerted the service upon non-standard values of related parameters.

3.Another project executed at the Institute was the project of Technical aid of automated processing the measured data of dosage input during monitoring the surroundings of Power Plant SE- EBO via the monitoring vehicles, then the display of measured data, vehicle position and data archiving on the control computer. The project was accomplished in 2003. The cooperation focused on technical aid in automated processing of measured data of dosage input during monitoring the surroundings of the Slovak Power Plant EBO. The position of vehicles was monitored and in case of need it allowed for communication with the vehicle crew so that the vehicle´s monitored route could be redirected or modified.

4. The project Design and implementation of IS for administration and claims control was carried out in 2005 for Gordic Consulting, Company, s.r.o. The cooperation was focused on the IS design and implementation for registering the clients, debtors, claims as well as for proposing their solutions, e.g. by defining a repayment schedule, etc.

5.The project executed in 2007 and titled as Modification of functionalities and software for teledosimetric system was prepared for SE-EBO, a. s, and aimed at the cooperation by the functionalities and software modification for automated processing of measured data of teledosimetric system in the Nuclear Power Plant in Jaslovské Bohunice.

6. In 2007 the design and implementation of ISTROCOUNT information system for Istropolitana D´arcy Company, s r. o., and advertising agency was carried out. It was aimed at monitoring the executed projects implementations by internal agency. Based on these data it was possible to state the price of individual project components and employees remuneration more accurately.

7. The information system design and implementation for the administration schedule of operations control was another project. It was aimed at monitoring the operation control of used devices as well as i t provided the service to have the view of devices to be controlled in a defined time period and plan the controls due to current needs.

8. The integration of IS MOFIS and TIS for EBO in 2009 was another significant project carried out at the Institute. The project was aimed at connecting the Mobile Filtration System (MOFIS) with the Technical Information System (TIS) and Dosimetric Information System (MIRSK) for EBO.

9. The last project is represented by the design of IS for BOGE Elastmetal Company - aimed at cars loading executed in 2013. The cooperation focused on designing and implementing software solution to monitor the freight transport for ZF SACHS Slovakia, a. s. The system registered the contract transport partners, their destinations, transport limits and tariffs. Based on the data the system allowed for more efficient transport planning and utilization.

2.2.4 Analysis of joined non-linear dynamic systems with fast feedback

Another research executed at the Institute is represented by the analysis of joined non-linear dynamic systems with fast feedback described by the system of 1st order differential equations.

Naming the systems as dynamic systems with fast feedback is based on the fact that for epsilon going to zero and with bounded right sides of the mathematical model it is tolerable if the related state quantities could grow unlimitedly in a random time interval point. The situation is typical for many interesting case studies related to phenomena occurring in non-linear systems, such as auto-oscillations, resonance, hysteresis, high-frequency oscillations and boundary layers phenomena. The mathematical framework for the systems with fast feedback is represented by the theory of singular perturbations.

Differential equations (systems) with a small parameter at a highest derivation are indicated as singular perturbed systems with regard to the principle invalidity of the joined dependence solution on the parameter and with regard to the related approximation problems in differential equations solutions in the surroundings of zero value of epsilon as well. The small epsilon parameter reflects the separation degree between the small and fast system channel, or mathematically, between the slow and fast system dynamics.

$$y_1' = f_1(t, y_1, y_2, \varepsilon)$$
$$\varepsilon y_2' = f_2(t, y_1, y_2, \varepsilon),$$

where $y_1 \in R^n$, $y_2 \in R^m$, with small positive parameter $\varepsilon << 1$ and joined functions f_1, f_2.

Generally, the oscillation control is aimed at two goals:
First, the suppression of oscillations means the acquisition of asymptotic stable zero solution valid for all initial conditions in the given sufficiently big area, second, the acquisition of oscillations with given properties, e.g. with frequency and amplitude which means the acquisition of asymptotic stable periodic solution valid for all initial conditions in the related field.

Regarding the singular perturbations, recent publications show wide possibilities of theory and technology implementation in the field of theory control. We can mention several applications:

1. Experimental devices in high energy physics (e.g. nuclear electronics) are frequently built of subsystems comprising the elements with slow and fast dynamics. Similarly, the high-frequency amplifiers operating in the frequencies above 1 MHz are often designed so that their input and output circuits comprise a resonance circuit or a resonance circuits system. Their practical utilization requires to define the exact relationship between the zone range of a non-linear circuit considered with regard to the resonance subsystem parameters in order to acquire the required range of frequencies and amplitudes on the output;

2. In the robotic manipulators the theory of singular perturbations is utilized for separate design of the slow (relates to the stable manipulator component) and fast (relates to the mobile manipulator component) transfer dynamics;

$$\dot{x}_1 = f_1(x_1, x_2) + \varepsilon g_1(x_1, x_2, \varepsilon)$$
$$\varepsilon \dot{x}_2 = f_2(x_1, x_2) + \varepsilon g_2(x_1, x_2, \varepsilon)$$
$$x_1(0) = a_1, x_2(0) = a_2$$

where $0 < \varepsilon << 1$.

3. In the realistic mathematical model describing the vertical helicopter movement landing on the base three different, nevertheless interconnected dynamics can be identified: angular speed of propeller blades (slow dynamics), vertical helicopter movement (fast dynamics) and lever dynamics of collective control (ultrafast dynamics);

$$\dot{x} = f(x, y, z)$$
$$\varepsilon_1 \dot{y} = g(x, y, z)$$
$$\varepsilon_1 \varepsilon_2 \dot{z} = h(x, y, z)$$

where $0 < \varepsilon_1\varepsilon_2 << \varepsilon_1 << 1$.

4. Singular perturbed boundary tasks occur in mathematical modelling of the heated bar stable states with a thermostat and described by a partial differential equation of a related format and with a stationary condition considering the time where the regulator keeps constant temperature equal to the sensor detected temperature in one of the selected places between the left and right end points, whereas the temperature change speed on the bar left end equals zero. In this case the homogenous bar with the length of $b-a$ sand with inhomogeneous temperature distribution is considered. Epsilon parameter represents thermal diffusivity. This way the singular perturbed tasks occur in the mathematical modelling of heat transfer with high Peclet number;

Obr.

$$\frac{\partial y}{\partial t} = \varepsilon \frac{\partial^2 y}{\partial x^2} + ky - f(x, y)$$

$$y'(a) = 0, y(b) = y(c), a < c < b$$

5.In biophysics, after a suitable variables normalization, Hopfield mathematical model of a neuron can be written as shown in Fig. 5.6 where μ_1, μ_2 are constants, and λ parameter is considered $\lambda > 0$ to be large. From the point of biophysics it represents the fact the neuron electric processes are fast.

$$\frac{1}{\lambda} y' = \mu_1 y + \mu_2 f\left(y(t-1)\right),$$

In the context of the mathematical analysis of fats feedback systems the Institute concentrates on two main aspects in their behaviour:

A) on analysing the systems in the interval of a definite length with the emphasis put on defining the conditions ensuring the existence of non-oscillatory model solutions and their approximations. Within the topic we concentrate on describing the phenomenon of boundary layers which is typical for singular perturbed systems. In general, the mathematical model solutions begin with a fast transfer and afterwards the solution remain close to the reduced task solution and the next transfer starts at the end of the interval considered. The boundary layers are formed as a result of irregular convergence of the exact solution to the reduced task solution in the surroundings of end points of the interval considered.

B) on controlling the amplitude and frequency of non-linear dynamic systems oscillation. The research of systems with fast feedback in th efield deals with the investigation of the existence and analysis of high-frequency oscillations of non-linear systems, e.g. for singular perturbed Duffing oscillators. The oscillators of the kind represent a structural mathematical model for the description and simulation of non-linear high-frequency circuits. Considering this, the Institute also dealsl with the systems with a complex structure of critical variable.